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10th Part of Report
No. AAEE/931/1

MINISTRY OF AVIATION

AEROPLANE AND ARMAMENT EXPERIMENTAL ESTABLISHMENT

BOSCOMBE DOWN

WESSEX H.C. MK. 2 HELICOPTER XR 588
(TWO GNOME ENGINES MK. 11001 AND 11101)

PERFORMANCE AND HANDLING TRIALS IN A MOUNTAINOUS AREA

U

PRESENTED BY

J. D. L. GREGORY,
PERFORMANCE DIVISION

AND

FLT. LT. C. R. VERRY,
FLYING DIVISION

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Performance and Handling Trials in a Mountainous Area

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J. D. L. Gregory, Performance Division
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A. & A.E.E. Ref: APF 105/07
Date of Trial: 1st to 19th September 1964

Summary

The report describes tests made on a Wessex Mk. 2 helicopter in the French Alps to assess its take-off and landing capability at altitude. Vertical performance results and handling recommendations are given. It was found that the altitude capability of the Wessex Mk. 2 in vertical flight was limited by the directional control available rather than by engine power.

This report is issued with the authority of

J R Bird.
Air Commodore,
Commandant, A. & A.E.E.

List of Contents

1. <u>Introduction</u>

Trials were required of a Wessex Mk. 2 helicopter to assess its landing and take-off capability at altitude. Preliminary tests (1) conducted by the manufacturer had shown that in low speed operation, the helicopter's capability was limited not by its vertical performance but by the adequacy of the yaw control, and a provisional clearance to Service with a recommended flight envelope was given on this basis. The present trials on XR 588 were conducted therefore with two separate objectives: firstly to examine the handling of the helicopter in landings and take-offs at altitude and secondly to measure its vertical performance. This report describes the tests carried out and from the handling aspect compares the results with the Firm's findings while the performance results are compared with those previously obtained on XR 498, a helicopter of similar type (2).

2. <u>Condition of aircraft</u>

The aircraft was a Wessex Mk. 2 fitted with extensive test instrumentation. Extended exhaust outlets were fitted as were a number of special external sand-sampling devices that had been used on tropical trials immediately prior to the present tests. The normal undercarriage was fitted (in place of an experimental wide track undercarriage used on the tropical trials) and all tests were conducted with an approximately neutral c.g. position.

3. <u>Limitations</u>

Flight and engine limitations were given by the Firm on Design Certificate Wes 2/XR 588/27 and are summarised below.

3.1 <u>Weight and c.g. position</u>

The maximum weight was 13,500 lb. and the c.g. range was from 7.0 inches forward to 9.0 inches aft of axis of reference.

3.2 <u>Height and airspeed</u>

Height - airspeed envelopes were given for rotor speeds of 220 and 230 r.p.m. and these are given in figures 1 and 2. A maximum pressure altitude of 12,000 ft. was given for the tests.

Maximum sideways and rearwards speeds were 30 knots estimated.

3.3 <u>Rotor speed</u>

Limitations were given as follows

	R.P.M.	
Condition	Max.	Min.
Power-on(3000 lb. ft. torque)	230	205
Power-off but with engine engaged	248	190
Power-off with rotor free-wheeling	258	190

/3.4 ...

3.4 Engine and transmission ratings

(Figures marked with an asterisk were limitations)

Rating	Engine Max. Contingency	Engine Inter Contingency	Engine Max. Continuous	Coupling Gearbox Max. Continuous
Total duration above lower rating	1 hr. 30 mins.*	30 hours*	-	-
Duration per application	2½ mins.*	1 hour*	-	-
Power turbine S.H.P.	1,350	1,250	1,050	800/800
Gearbox output S.H.P.	1,300	1,200	1,000	1,550
Compressor speed R.P.M.	26,750*	26,300*	25,300*	24,050
Power turbine speed R.P.M.	19,440	19,440	19,440	19,440
Rotor speed R.P.M.	230*	230*	230*	230*
P.T.I.T. °C	710*	685*	635*	580
S.F.C. lb/H.P./hr.	0.618	0.624	0.641	0.700
Torque lb. ft.	2,700*	2,500*	2,100	3,200*

4. Performance tests made and results

The performance tests included hovering and vertical climb tests at altitudes from 800' to about 8,000'. Tethered hovering was carried out at an altitude of about 6,000'. For power measurement the pilot's torquemeter was used with the cockpit rotor speed indicator. Weight measurement was handicapped by the inadequacy of the fuel contents gauges, so as far as possible all flights were started with the tanks full and the fuel used was taken from the fuel gone counter. This, checked against the amount of fuel put into the helicopter after each flight, gave a probable accuracy of about 75 lb. Rate of climb was measured by watch and altimeter.

The results of all the hovering tests are plotted non-dimensionally in figure 3. It will be seen that a fair amount of scatter is present and this is attributed to the difficulty of accurately recording the torquemeter in hovering flight. Wind strength and direction were determined by an observer on the ground, and in most cases the wind strength did not exceed 5 knots and was frequently very light and not measurable. A plot was made to see if any correlation existed between the scatter of the results and the measured wind speed but none could be found.

Figure 4 compares the basic hovering performance for XR 588 with that previously obtained on XR 498 (2). It will be seen that the present tests show generally good agreement with the previous tests, there being a small increase in hovering power of about 3%.

Figure 5 shows the vertical climb performance of the helicopter. This also shows good agreement with previous tests.

/Most ...

Most of the trials were made using a rotor speed of approximately 230 r.p.m. The area of the explored envelope could have been much extended by the use of lower rotor speeds, particularly during the tethered hovering tests but this was considered inadvisable in view of the high vibration level and yaw control problem at low rotor speeds.

5. Handling tests made

The Firm had carried out extensive tests in the low speed regime of flight and had investigated the use of rotor speeds of 220 and 230 r.p.m.(1). Operating limitations were recommended in terms of weight, height and air speed for both rotor speeds and a significant conclusion from these tests was that yaw control was a limiting feature in manoeuvre in hovering flight and vertical climb. In these flight conditions in particular, the use of 2 inches or more of left rudder control displacement could result in tail rotor stall conditions, consequent high power absorption by the tail rotor and a resultant "overtorqueing" of the main rotor transmission in maintaining the flight condition.

With this background, handling tests were carried out in the French Alps with particular attention being paid to take-off and landing and low speed manoeuvres. Experience was also obtained of transporting equipment in the shape of external loads of 1,700 lb. to a site at 6,000 ft. for the purpose of tethered hovering tests.

The weather was generally fine during the period of the trials, with light winds up to 12 knots and only light turbulence.

6. Results of handling tests

6.1 Approach and landing

As most mountain landing sites were restricted areas situated on ridges no ground effect assistance was possible until the hover had been established over the landing point.

Approaches were carried out at various angles in order to establish a technique which would permit landings at the highest possible weight compatible with satisfactory yaw control and torque limitations.

Approach angles of 20° or above invariably produced very high torque values, particularly at high all up weights, due to the amount of left rudder required during transition to the hover.

At more shallow angles of approach, less than 15°, a power setting more closely related to that required to establish the hover could be used, this reducing the need for a large power change and consequently the amount of left rudder. Also the flat high power approach gave an early indication of the left rudder and torque likely to be required to effect a landing.

A speed of 20 - 30 kts. was found to be the optimum for this type of approach with the aim of reducing speed slowly and establishing a low hover over the intended landing point without a marked attitude change.

Above 20 kts. the vibration level was low but during transition to the hover a very marked increase was apparent. This vibration reduced once the hover was established.

/Landings ...

Landings were made initially at weights well below the provisional limitations and then the weight was increased progressively. It was found that in the non-turbulent conditions that generally prevailed it was possible to land without difficulty on or just over the proposed weight limit. However if slight turbulence were present it was very easy to exceed the torque limit. Such landings were judged 'marginal'. Figure 6 shows a representative plot of landings. It will be seen that for fairly smooth conditions the tests generally confirm the provisional limitations given for both 220 and 230 r.p.m. Although it was easy to overtorque by use of the directional control lack of control response was never apparent during the landings.

6.2 Low speed manoeuvres

Sideways flight, spot turns and vertical climbs were carried out, once the hover had been established. Owing to the nature of the terrain however protracted sideways flight in ground effect was not possible.

Out of ground effect the limiting speed was restricted when flying to the right by large left rudder pedal requirements and consequent high torque values. At altitudes above 5,000 ft. vibration from the tail rotor and a lack of directional control became noticeable if speed was increased above approximately 10 kts. At speeds below this, sideways flight to the right was straightforward. Sideways flight to the left, at speeds up to approximately 20 kts., was satisfactory.

Spot turns through 360° were carried out in ground effect without difficulty at all altitudes.

Vertical climbs were possible at all altitudes without any sudden control problems. Having established the torque required to hover it was found that, at the same weight, at least 300 lb. ft. was available for vertical performance without encountering yaw control problems. During vertical climbs at high collective pitch angles and high weight some vibration in the form of "vertical bounce" was apparent.

6.3 External load carrying

In order to provide a tethered hovering facility at high altitude the opportunity was taken during this trial to establish a site on Mt. Marjorie at approximately 6,000 ft. and equipment was flown up to the site using the standard external load carrying attachment, with Rollason hook, and a 10' steel strop.

The equipment consisted of 4 concrete blocks, 4' x 4' x 1'6" weighing 1,700 lb. each, "threaded" on to a 1½" diameter bolt and each block was flown separately.

In order to avoid overflying built up areas the load was transported by road to a convenient pick up point at the foot of the mountain. From here to the delivery point was about 5 mins. duration including a 3,000 ft. climb.

The first block, which was lifted with a 6'6" assembly bolt attached directly to the strop, developed a marked lateral swing as speed was reduced during approach to the hover. This swing, which could be felt in the aircraft, persisted for some time after the hover had been established but finally damped out. During lift-off and forward flight the load handled well.

/The ...

The remaining three blocks were lifted with a special four point attachment sling fitted to bolts set into the blocks. These loads handled well during all stages of flight including forward flight up to 80 kts. at 5,000 ft. An observer in the main cabin was able to confirm that the load did not swing or spin but trailed in a very steady manner at all times including transition to the hover.

All up weight including the external load at the commencement of the test was approximately 12,200 lb.

6.4 <u>Take-offs</u>

Take-off was straightforward at all altitudes, "overtorqueing" being encountered only during transition to forward flight. This occurred at high weight if a high torque value was selected as forward flight was initiated. If the transition was conducted with the minimum necessary increase in torque a suitable margin was normally available in the event of large left rudder pedal movements being necessary.

6.5 <u>General</u>

Some landings and take-offs were carried out with the auto-stabilisation equipment at standby and although this was found acceptable, operation with the auto-stabilisation equipment engaged was found preferable.

The standard undercarriage was used throughout the trial and no "padding" was encountered. Landings on 10° slopes, at 6,000 ft., were made satisfactorily. The landings were normally made with tailwheel locked and brakes on. This was found particularly desirable when landing on uneven or sloping ground.

7. <u>Discussion of results</u>

During the trials, as it became apparent that the greatest limitation in vertical operation was the tail rotor power requirement, it seemed expedient to seek some way of simplifying the presentation of limitations for use by squadron pilots. Accordingly the performance results were used to calculate as a function of weight and altitude the hovering performance of the Wessex at constant collective pitch. This is shown in Figure 7 with, for comparison, the Firm's provisional limitations. It will be seen that the "vertical operation" and "limited manoeuvre" lines occur always at about 8.8 and 9.8 degrees collective pitch respectively irrespective of weight, altitude or rotor speed. Thus it would seem that the limitations might be expressible simply in terms of collective pitch and it is suggested that more work be done to investigate this.

8. <u>Conclusions and recommendations</u>

8.1 In general the helicopter handled well in high altitude conditions, particular conclusions and recommendations are made below. and the trials confirmed the general validity of the Firm's investigation of the behaviour of the Wessex Mk. 2 at low air speeds. The helicopter's handling characteristics in vertical flight are limited by the ease with which the tail rotor can be stalled, leading not so much to a loss of directional control as to "overtorqueing" of the transmission . The Firm's recommended limits for vertical operation, subsequently incorporated into a Special Flying Instruction (S.F.I. Wessex 26), have been generally confirmed but it is probable that these limits are unrealistic for turbulent conditions.

/8.2 ...

8.2 The manoeuvre capability near the limiting condition for vertical operation is fairly restricted. Although spot turns were possible in light winds, sideways flight to the right was limited to an estimated ten knots.

8.3 No problems were encountered with the conventional narrow-track undercarriage.

8.4 The great advantage to be derived from the use of an increased datum rotor speed of 230 r.p.m. (at 3,000 lb.ft. torque) compared with the normal 220 r.p.m. has again been demonstrated, and it is highly desirable that the impedimenta (lack of engine and transmission clearances) to the use of this rotor speed in Service should be removed as quickly as possible.

8.5 The vertical performance results obtained during the trials show good agreement with those obtained during the tropical trial on XR 498. It is unfortunate that the handling problems associated with the tail rotor do not permit this good vertical performance to be fully used.

8.6 Further tests, now being undertaken, should attempt to define a vertical flight operating envelope in terms of the rudder control margin available for manoeuvre, so that the best guidance can be given to Service pilots without unduly penalising the helicopter.

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Ref. No.	Title, etc.
1	Westland Aircraft Limited. Wessex 5, Flight envelope and ground resonance investigation. Interim report.
2	Gregory J. and Anderson Sqdn. Ldr. W.A. Wessex 2 Performance and handling trials in tropical conditions. A. & A.E.E. Report No. 931/1, part 4.

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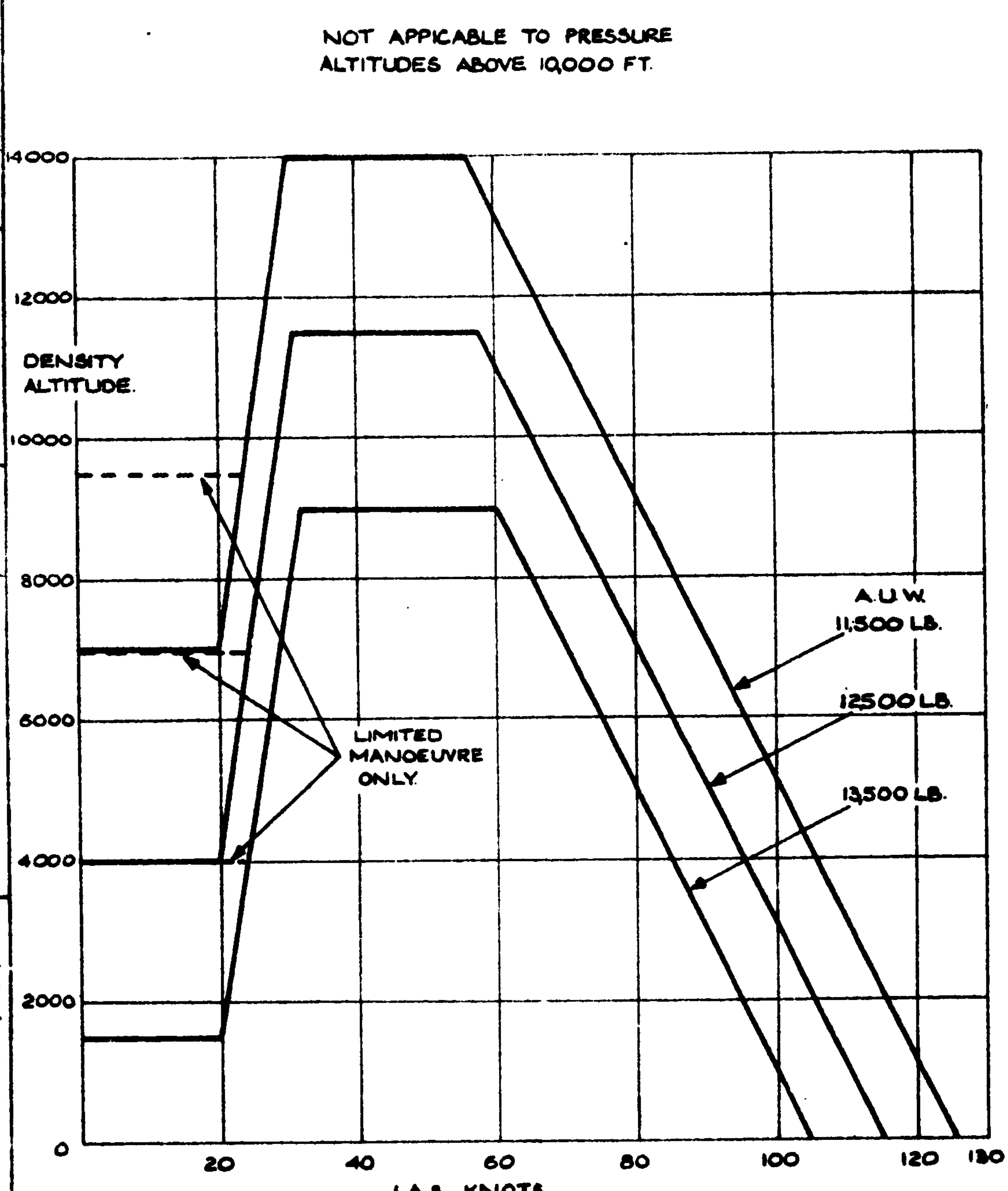
FIG. 1.



FIRMS PROPOSED FLIGHT ENVELOPE 220 R.P.M.

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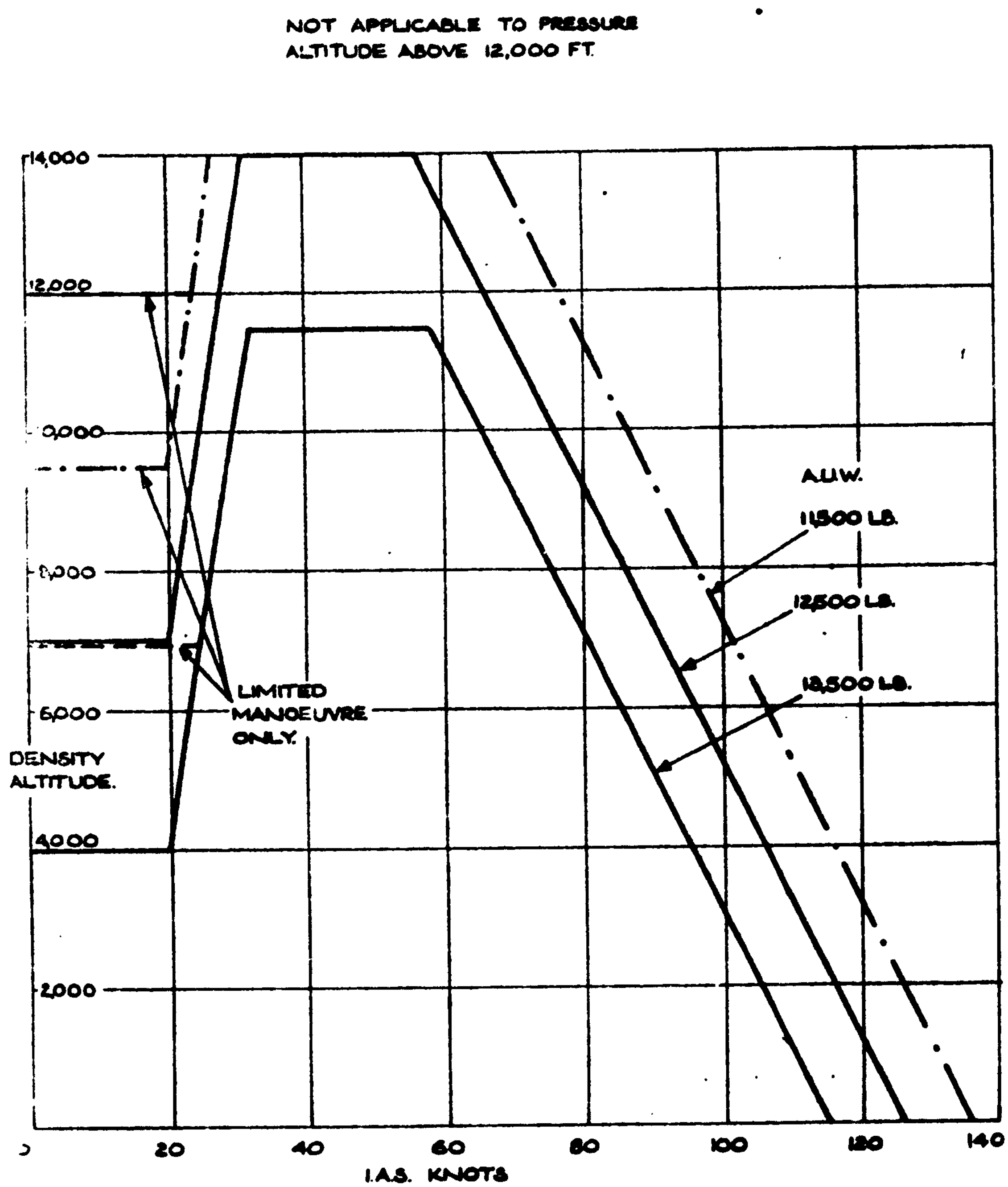
FIG. 2.



FIRMS PROPOSED FLIGHT ENVELOPE 230 R.P.M.

GREGORY. APP.
WESSEX Mk.2
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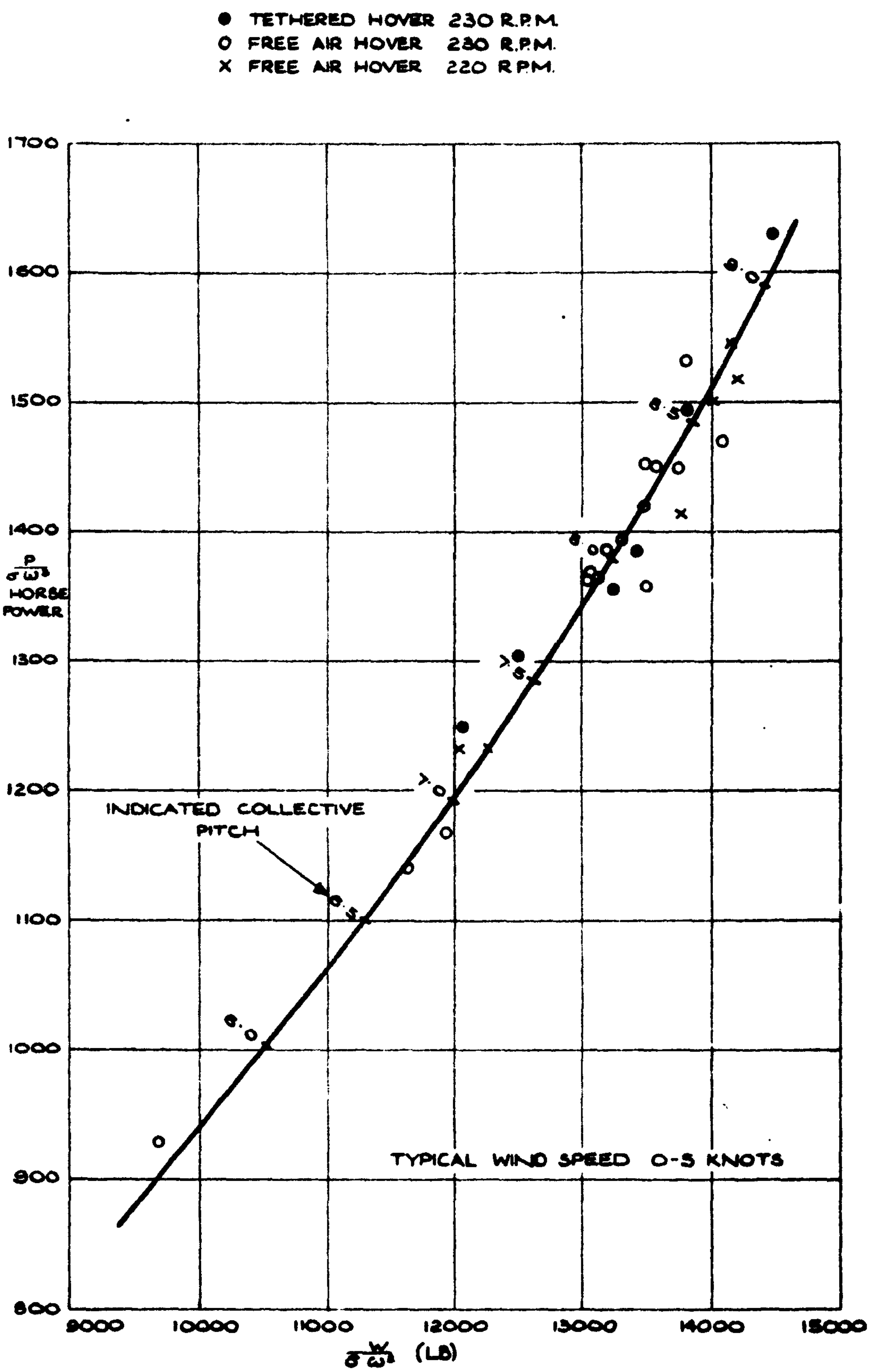
FIG. 3.



HOVERING PERFORMANCE.

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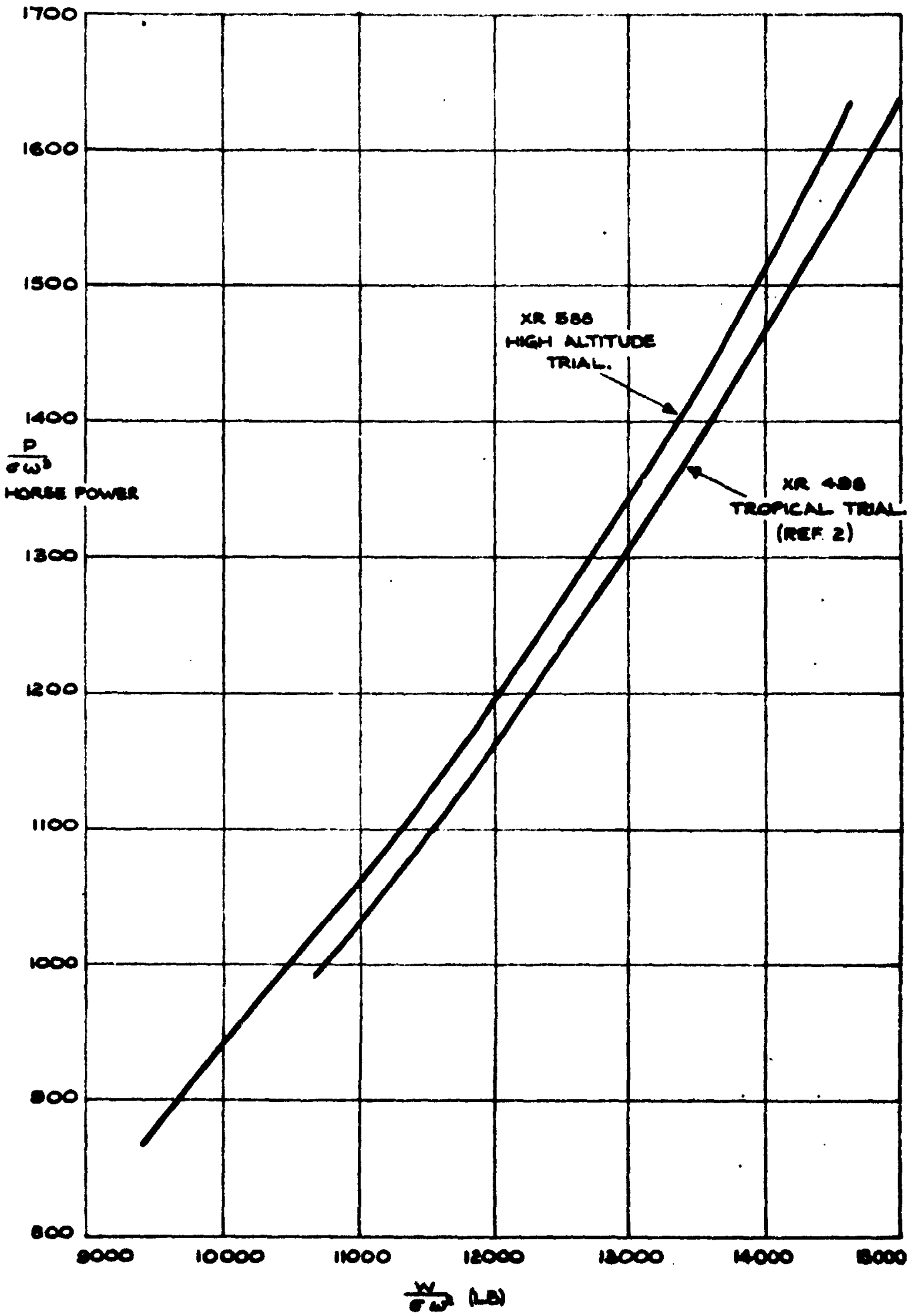
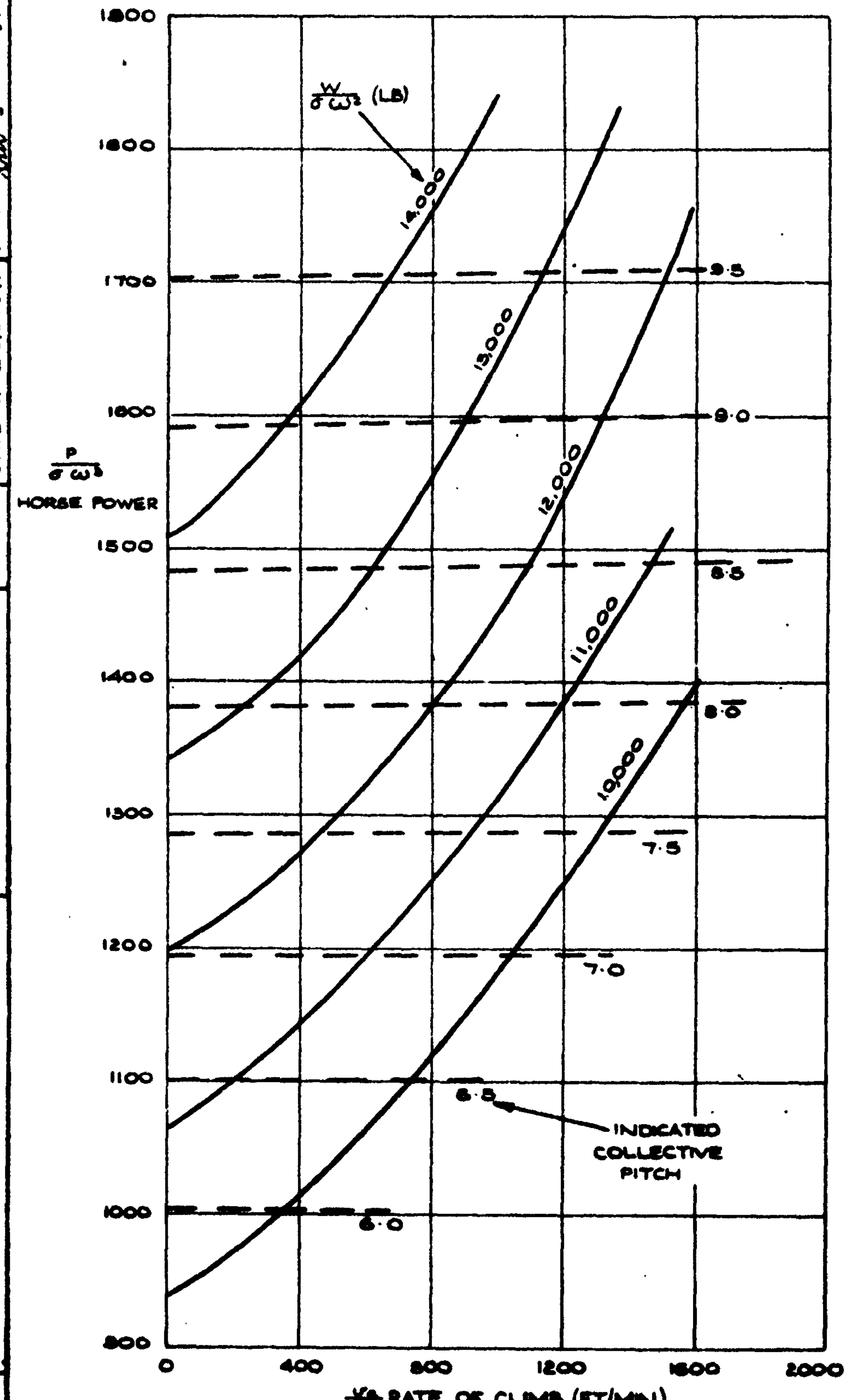
FIG. 4.



COMPARISON OF HOVERING PERFORMANCE WITH XR 498.

SK.N°B2867 | 10TH PART OF REPORT N° A.&A.E.E./931/1 | WESSEX MK.2 XR 588 | TR. K.G. | CH. J. GREGORY | APP. for S of P | 15.1.65

FIG. 5.



VERTICAL PERFORMANCE.

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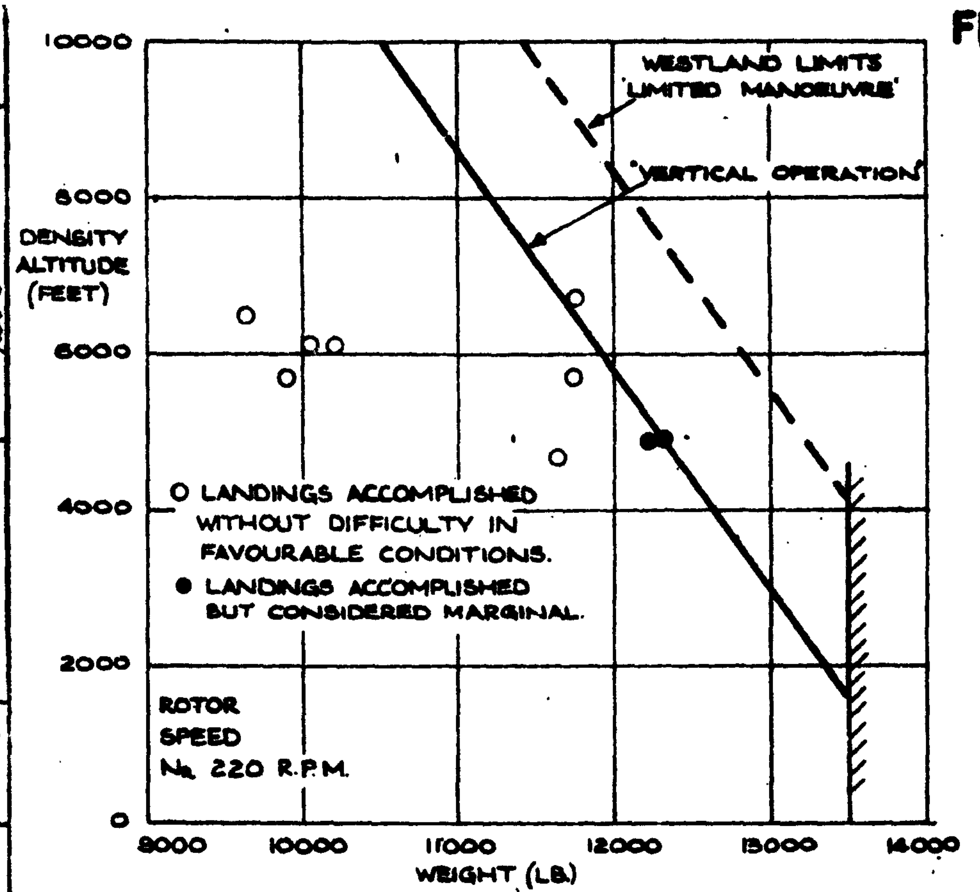
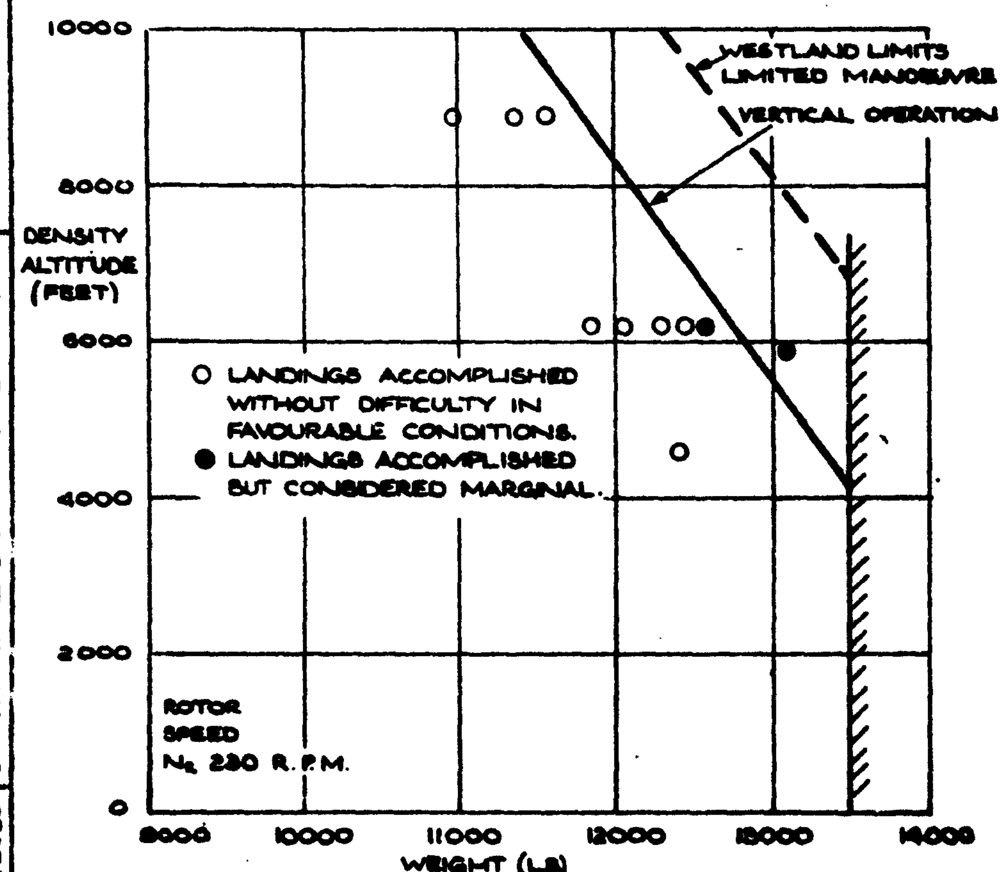
FIG. 6.





COMPARISON BETWEEN LANDINGS MADE AND WESTLANDS PROPOSED ENVELOPE.

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FIG. 7.

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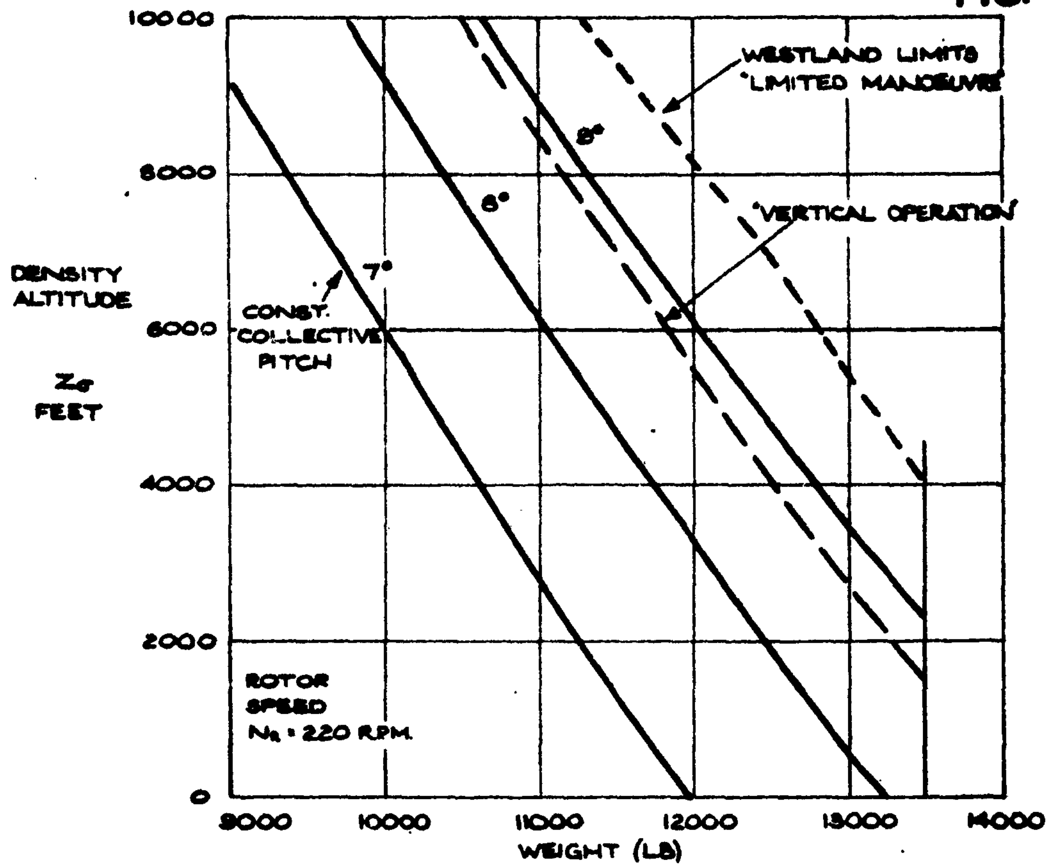

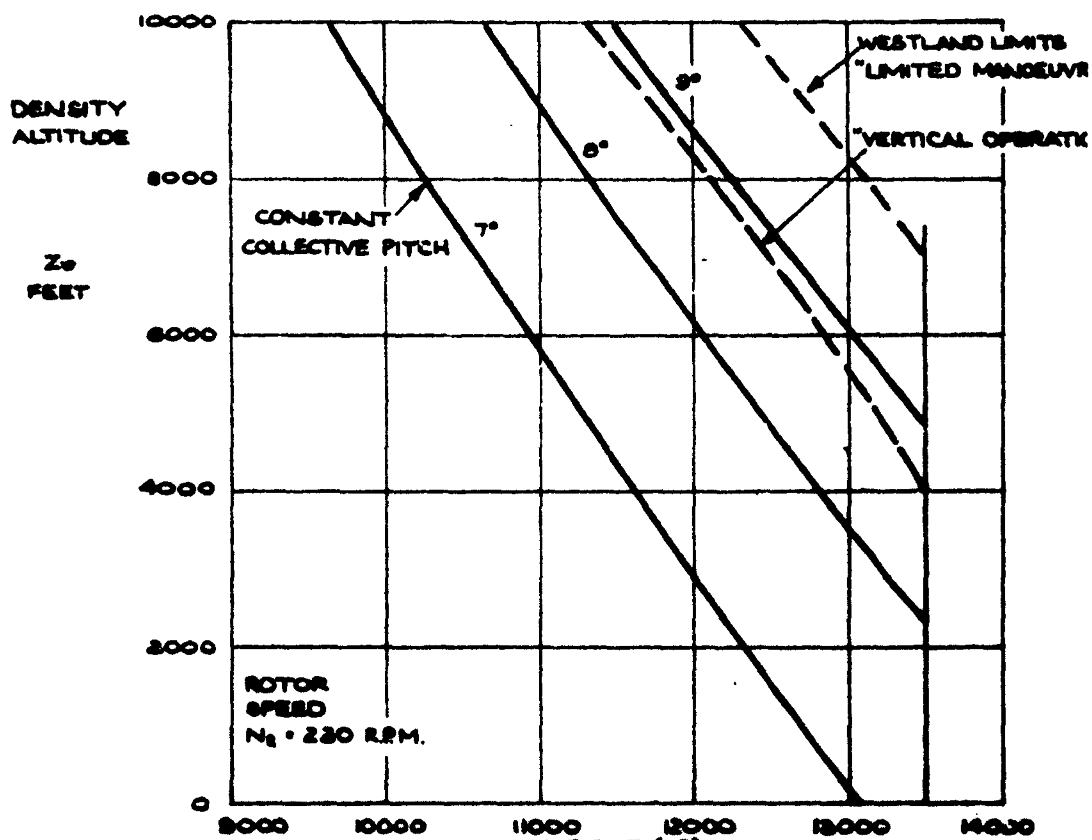

HOVERING CAPABILITY OF WESSEX MK.2 IN TERMS OF COLLECTIVE PITCH.

FIG. 8.

WESSEX MK.2 XR 588, LANDING AT 9,000 FEET DENSITY ALTITUDE IN THE REGION OF MT. BLANC.

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